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Augmented Reality for Smartphones

A Guide for developers and
content publishers

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Introduction to Augmented Reality in Smartphones

This report should help developers and content publishers who want to take advantage of the latest developments in smartphone and augmented reality (AR) technology to create novel and exciting new learning experiences. Not so long ago, augmented reality was an experimental technology that rarely left the lab and required a high level of technical expertise and knowledge to create new applications. Now, thanks to advances in smartphone hardware, AR technology is much more available and easily accessible for users and developers alike.

With several innovative young companies offering out the box AR “browsers” and tools for creating, publishing and hosting virtual content, it is even possible to create augmented reality experiences without any programming knowledge at all. Many new applications and frameworks have been launched, each with its own set of capabilities and requiring different levels of technical knowledge to publish content and customize the interface. This report will help you to navigate this emerging landscape and pick out the best tools and platforms for your needs.

As this report is written primarily for developers it will focus its analysis on browsers and platforms that allow some level of customization or ability to publish your own content rather than the many standalone applications where both content and interface are tightly controlled by the vendor. However it will briefly describe some other applications that might be useful in a teaching and learning context. It will also take a look at the various tools and hosting platforms that are available to make it easier to create and share Point of Interest (POI) content and draw together best practice on implementing POI services.

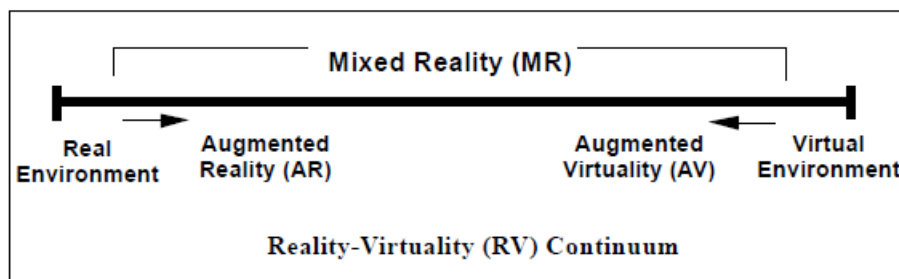
Being able to share the same content across platforms is also an important consideration in embarking on a project that aims for sustainable output. With this in mind, this report will discuss the initiatives that have recently sprung up to define new standards and protocols around the emerging Augmented Reality industry. As this is still a technology in its infancy it is important to understand its limitations, particularly in the area of user experience. Current work on user experience patterns in augmented reality will be reviewed. Finally a look will be taken at augmented reality in education to provide some inspiration for educators interested in deploying this technology in a teaching and learning context.

It is intended that this report will equip developers and content publishers with all the information they need to make the right decisions about where and how to employ this inspiring new technology and create some exciting innovations in teaching and learning.

Augmented Reality Key Concepts

In this report terminology has been kept to a minimum to make the discussion as accessible as possible. A brief definition of augmented reality technology is provided below with some helpful descriptions of terms and concepts that will crop up throughout this report. For more comprehensive overview of the history and technical background of AR technology the reader is referred to resources at the end of this section [1,2,3,4,5,6].

There are plenty of definitions of augmented reality but the general assumption in this review is that augmented reality enables an enriched perspective by superimposing virtual objects on the real world in a way that persuades the viewer that the virtual object is part of the real environment. Therefore Augmented Reality is a crossover between the real and virtual world, as illustrated by Paul Milgram's famous Reality-Virtuality (RV) continuum diagram [7] shown below.



Reality-Virtuality Continuum, Milgram, Takemura, Utsumi and Kishino [7]

Some definitions of Augmented Reality (AR) insist the virtual object is a 3d model of some kind, but most people accept a looser definition where the virtual domain consists of 2d objects such as text, icons and images. There is further fuzziness in definition where multimedia content (video or audio) and visual search capabilities are promoted as augmented reality applications. While these “mediascape” [8] systems certainly augment reality, it's unlikely that the viewer will perceive them as part of the real environment although some level of immersion is possible [9]. These kinds of user experience blur the boundaries between Augmented Reality, Location Based Services and Visual Search.

Below are some key concepts and terms to enable the reader get up to speed on augmented reality technology.

Reality View:

Refers to the video stream produced by the smartphone camera. This is the same feed that the user sees when they use the smartphone's regular camera application. The AR application captures images from the video stream, augmenting the live feed with virtual objects to create an *augmented view*.

Registration and Tracking:

Describe the methods available for aligning a virtual object with a 3-dimensional co-ordinate in the reality view. For smartphone applications, object tracking involves either location sensors such as GPS, digital compass and accelerometer (*location based tracking*) or an image recognition system (*optical tracking*) or a combination of the two.

Point of Interest (POI):

Is an individual data item typically associated with a geographic location (longitude, latitude, altitude) or a visual pattern (marker, book cover etc.) that can be rendered in some way by the AR application. The Point Of Interest data type must provide a description of the location or reference image used in tracking and the type of content to be rendered. Normally the content itself (3d model, image etc.) is not part of the Point Of Interest, but a link to the content is provided instead.

Virtual Object:

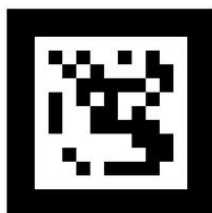
Some kind of digital content that is rendered by the AR application and superimposed on the reality view. Typical content includes 3d models, 2d images, icons and text.

Channels, Layers and Worlds:

All refer to published groupings of related POI's and associated virtual objects. Often channels provide access to all the content of a single content publisher (e.g. Flickr, Cafes, Wikipedia).

Markerless vs Marker based AR:

Where image recognition is used to align a virtual object (optical tracking) there is a distinction between systems that identify an artificial *fiduciary marker* (2d matrix code or Light Emitting Diode) placed at locations or on objects in the real world and those that use *natural feature detection* to identify unaltered real world objects such as book covers, posters or landmarks that have no artificial makers to assist object recognition. In each case, the 2d or 3d virtual object appears to be “glued” to the marker or natural feature when seen through the AR viewport.



A 2d-matrix code (Junaio Glue LLA marker) and Junaio application showing virtual information button aligned with a marker in museum. source:

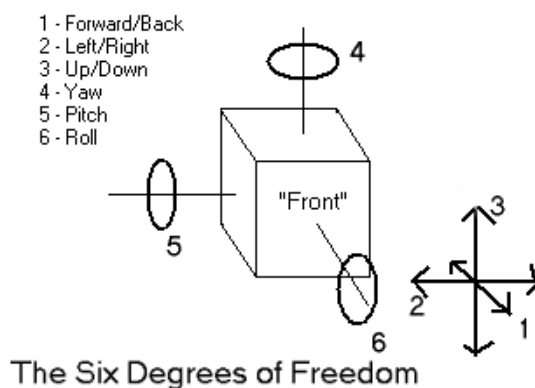
<http://junaio.wordpress.com/2010/03/30/523/>

Location Based Tracking:

Refers to tracking based on geo-location information obtained from the device's location sensors (longitude, latitude, altitude, compass bearing, accelerometer readings for pitch and roll). This term is used to make a distinction between systems that rely on location sensors alone in contrast to systems that can track objects using optical (image recognition) techniques. Location based tracking is generally less accurate than optical methods and only works in outdoor environments.

Six Degrees of Freedom:

Refers to the ability of the tracking system to maintain alignment of a real world object in three dimensional space. For a typical smartphone AR application, 6 degrees of freedom are possible. Location sensors are able to provide forward/back and left/right, up/down (GPS) and yaw (compass) and the accelerometer can indicate pitch and roll of the device. Similarly image recognition techniques can calculate angles from a known reference orientation.



Source Wikipedia [14]

Near Field Communication:

The next generation of smartphones are likely to support Near Field Communication (NFC) [10,11]. Near Field Communication is based on short range wireless (typically less than 4cm) technology involving an active "initiator" chip and a passive "target" that can be activated by the initiator radio field. This means the passive target does not need batteries and can take highly flexible and portable forms including cards (e.g. Oyster card [12]), key fobs, stickers and tags. NFC may feature in future augmented reality systems, possibly replacing matrix code markers for indoor object tracking [13].

Resources

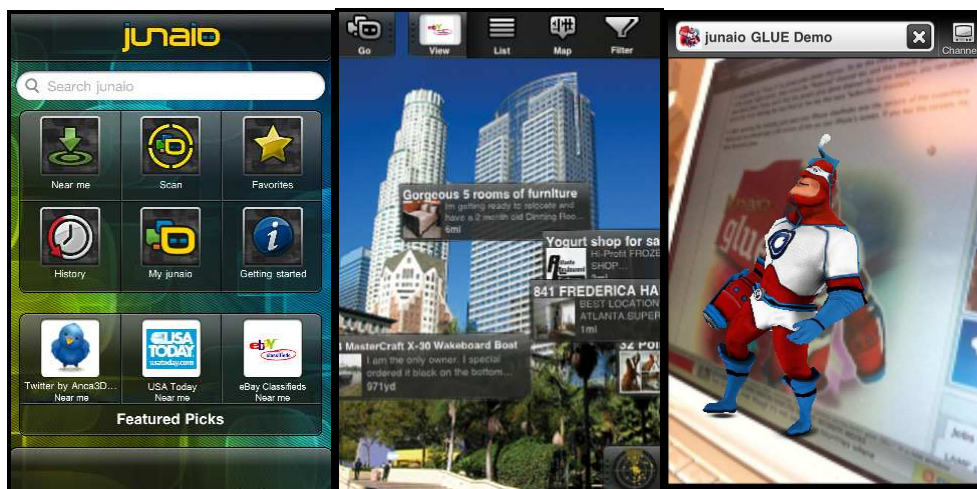
- [1] History of Mobile AR, Christian Doppler Laboratory for Handheld Augmented Reality, <https://www.icg.tugraz.at/~daniel/HistoryOfMobileAR/> (accessed 26/01/2011)
- [2] Augmented Reality Year in Review – 2010, Thomas Carpenter, <http://thomaskcarpenter.com/2011/01/03/augmented-reality-year-in-review-2010>
- [3] Lester Madden, Nitin Samani “iPhone Augmented Reality Applications Report”, June 2010, Augmented Planet http://www.augmentedplanet.com/wp-content/uploads/report/iPhoneApplicationReport_v1.pdf (accessed 26/01/2011)
- [4] Foteini Valeonti , “Getting To Know Augmented Reality”, May 2010, <http://valeonti.com/?p=331>, (accessed 26/01/2011).
- [5] Feng Zhou, Henry Been-Lirn Duh, Mark Billinghurst, "Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR," Mixed and Augmented Reality, IEEE / ACM International Symposium on, pp. 193-202, 2008 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, 2008.
- [6] Douglas Dixon , February 2010, Augmented Reality Goes Mobile: Trends in Augmented Reality for Mobile Devices, http://www.manifest-tech.com/society/augmented_reality.htm (accessed 26/01/2011)
- [7] Milgram, Paul; H. Takemura, A. Utsumi, F. Kishino (1994). "Augmented Reality: A class of displays on the reality-virtuality continuum" (pdf). Proceedings of Telemanipulator and Telepresence Technologies. pp. 2351–34.
http://vered.rose.utoronto.ca/publication/1994/Milgram_Takemura_SPIE1994.pdf (accessed 18/01/2011)
- [8] HP mscape, <http://www.hpl.hp.com/mediascapes/>, HP Labs accessed 15/02/2011
- [9] J. Reid, E. Geelhoed, R. Hull, K. Cater and B. Clayton **Parallel Worlds: Immersion in Location-based Experiences**. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pages 1733- 1736. ACM, April 2005.
- [10] Bill Ray, November 2011, The Register, “iPhone to tap NFC – rumours say” http://www.theregister.co.uk/2010/11/02/apple_nfc_again/ (accessed 15/02/2011)
- [11] Android Developers Reference, NFC API, Google, <http://developer.android.com/reference/android/nfc/package-summary.html> (accessed 15/02/2011)
- [12] Oyster Card, Wikipedia, http://en.wikipedia.org/wiki/Oyster_card (accessed 15/02/2011)
- [13] Chad Catacchio, December 2010, “Why The Nexus-S has NFC. Google Places Window Stickers Have NFC Capabilities”, The Next Web, <http://thenextweb.com/google/2010/12/10/why-the-nexus-s-has-nfc-google-places-window-stickers-have-nfc-capabilities/> (accessed 15/02/2011)
- [14] “Six Degrees of Freedom” Wikipedia, http://en.wikipedia.org/wiki/File:6_degrees_freedom.png (accessed 18/01/2011)

Augmented Reality Browsers for Smartphones

AR Browser Quick Overview

Junaio AR Browser

Junaio [1] is a powerful AR browser from the German company Metaio. Features include support for 3d object rendering, location based tracking and both marker and markerless image recognition. There is a powerful API for developers including the “Junaio Glue” API [2] for anchoring 3d objects to a marker or markerless pattern. Junaio also offers a publishing and hosting service for content publishers. At the moment, Junaio is the only “browser” style AR application that has built-in optical tracking capability, which is a major advantage given the limitations of location based tracking (i.e. poor GPS accuracy in some locations and no indoor tracking capability).



Junaio [1] (left to right): home page, POI icons and 3d image “glued” to markerless 2d pattern

Layar AR Browser

Promoting itself as the “world’s first AR browser” Layar [3], from a start-up company based in Amsterdam, is the most prominent and best partnered of the new breed of application designed for smartphone devices. It offers animated 3d rendering, location based tracking, has a highly flexible API and a useful set of tools for developers. Layar can also direct publishers to several 3rd party content management tools and hosting companies to help publishers create their own content and publish channels (called Layars). As well as creating one of the most compelling

user interfaces, Layar has been very successful in partnering with manufacturers of handsets and comes pre-installed on the Samsung Galaxy and has also been promoted for the Verizon Droid.



Layar [3]: (left to right) POI thumbnails, 3d “floaticons”, “Nearby” POI list view

Sekai Camera AR Browser

Sekai Camera [4] from the Japanese based Tonchidot Corporation promotes itself as a social network application, allowing users to post their own content such as photos, images and text messages that their friends can discover and comment on. It employs location based tracking and offers developers and content publishers an API (subject to fee).



Sekai Camera (left to right): user generated tag POIs and game interface based on browser

WikitudeWorlds Browser and Wikitude API

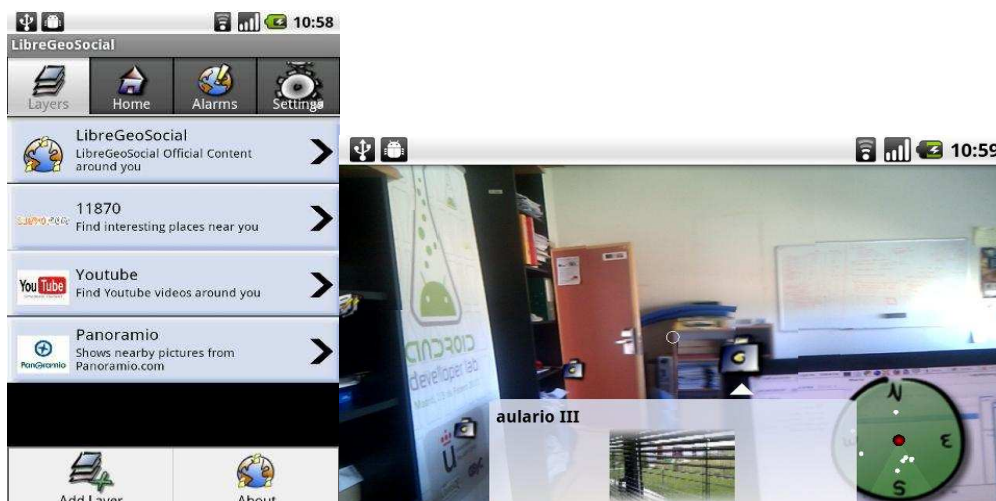
WikitudeWorlds [5] is a general purpose browser from Austrian start-up Mobilizy. With location based tracking and support for 2d images, its open publishing model makes it one of the most accessible browsers for developers. The Wikitude Worlds Browser is based on the *Wikitude API*, an open source framework for developing your own standalone AR applications on iPhone, Android and some Symbian based (Nokia) devices. Developers have full access to the source code and some skeleton applications to get started.



Wikitude Worlds[5]: POI icon and expanded POI information text box

LibreGeoSocial Open Source Browser

LibreGeoSocial [6] is a community based project aiming to create an extensive open source framework for social network enabled AR applications. A prototype browser is available to download (for Android) and developers can access both client and server side code along with a powerful developer API. The reference implementation uses location based tracking and plugin code is available with some visual search / image recognition capability. Support for social network and tagging is also built into the reference browser app.



LibreGeoSocial [6] Open Source Browser: layer selection and POI view

AR Browsers in Depth

This section provides a classification of augmented reality browsers that aims to assist developers and content publishers to decide which application best suits their needs (see also Rose et. al [7] and W3C POI WG [26]). The classification is based loosely on Papagiannakis et al. [8] but adapted to meet a narrower scope of applications recently made available on smartphone devices. A Comparison Table created using the classification is shown below.

Product	GPS	Mrkr basd	Mrkr Less	Built-in User Actns	Pblsh API	App API	AR View Content	POI actions	Offline mode	Pltfrm
Layar	Yes	No	No	Web View	open key	custom	3d,, 3d-anim, 2d	Info, Audio, Music, Video, Call, Email, SMS, Map, Event	Online only	iPhone, Android, Symbian
Junaio	Yes	Yes	Yes	Post text, Post image, Post photo, Post 3d, social	open key +, crowd	custom	3d, 3d-anim, 2d	Info, Audio, Video, Map, Event,	Online only	iPhone, Android, Nokia (N8)
Wikide API	Yes	No	No		Bndle	open	3d, 2d	Info, Event	Offline	iPhone Android
Wikide Worlds	Yes	No	No		open, key	custom	2d	Info, Map, Email, Call	Cachble	iPhone Android Symbian
Sekai Camera	Yes	No	No	Post text, Post photo, Post sound, social	restr + crowd	comm	2d	Info, Audio, Map, Social	Online only	IPhone, Android, iPad, iPodTouch
Libre Geo Social	Yes	src	plugin	Post text, post picture, post sound, social	crowd + open src	open	2d	Info, Audio, Map, Social,	Online only	Android

AR Browser Comparison Table

For future updates to table see <http://mobilegeo.wordpress.com/2010/11/23/comparing-ar-browsers/>

The criteria and explanation of terms used in the Comparison Table are explained below.

Browser Evaluation Criteria

Criteria 1: Registration and tracking (columns 2 to 4)

This part of the table indicates the methods available for aligning a virtual object with a 3 dimensional co-ordinate in the reality view. The tracking methods evaluated in the table rely either on GPS and location sensors (less accurate) or computer vision (more accurate) or both.

1. **GPS** [location sensor based] (column 2)
 - **Yes:** supports location based tracking using GPS, digital compass and accelerometer.
 - **No:** does not support location based tracking or limited support
2. **Mkrbasd** [Marker based] (column 3)
 - **Yes:** built-in support for optical tracking using markers such as 2d matrix.
 - **Src:** source code available to support optical tracking using markers.
 - **No:** does not support optical tracking with markers.
3. **MkrLess** [Markerless] (column 4)
 - **Yes:** built-in support for optical tracking using natural feature detection and/or image recognition.
 - **Src:** source code available to support for optical tracking using natural feature detection and/or image recognition.
 - **No:** does not support tracking with feature detection or image recognition.

Criteria 2: Built in user actions (column 5)

This column lists actions the user can perform using the browser that are not related to any particular channel or point of interest. The most basic action is the ability to search for points of interest in the user's vicinity and visualize the search results in an AR view. The Layar browser allows developers to define user "intents" as part of a published channel, giving developer freedom to embed any web based functionality into the interface. In this case user actions are part of the channel rather than part of the browser.

- **Post text:** User can post a text message to the current location / orientation of the handset. Often users can choose a 2d icon or sometimes a 3d icon to represent the message in the browser reality view.
- **Post image:** User can post an image already in the handset gallery to the current location /orientation of the handset.
- **Post photo:** User can take a picture using the device camera and then upload the image to the POI server.
- **Post 3d:** User can select a 3d model and make it viewable to public or friends at the current location / orientation of the handset.

- **WebView:** Developer can offer arbitrary web based services to a user through an embedded web view.
- **Social:** User has access to social network platform including common actions such as follow, invite, comment etc. Typically users generate content such as text messages which only friends in their social network can see.
- **Visual Search:** user can take photo of an real world object such as a book cover and obtain information about the object using image recognition technology.

Criteria 3: Publishing API (column 6)

All of the browsers we have evaluated offer some way for developers to publish their own content (Points of Interest) so that users can search and interact with the content in the browser application.

- **Open key:** Platform provides an API that allows developers to publish their own data. For open keys there is no registration fee for developers and no practical limit on the users' access to the published content. This also includes platforms that allow developers to publish their content without any key or registration at all.
- **Crowd [crowd sourced]:** Crowd sourced content is published by regular users using facilities available in the browser itself. Typically, images, audio clips and text as well as a predefined gallery of 3d objects are available for crowd sourced content publishing. This has the disadvantage the developer has to physically visit the place where the content is tagged, but enables non-technical people to get involved in creating content.
- **Restr[icted key]:** A publishing API is available but some kind of fee or restriction on use is applied by the platform provider.
- **Bundle [Bundled]:** Content is bundled into the app itself. This assumes developer has access to the browser source code and can therefore create and publish their own app for download. While this has the disadvantage of cached data becoming stale if the user does not regularly update the app, the ability to search for POI offline is an advantage for some use cases where 3G connectivity is unavailable or prohibitively expensive.

Criteria 4: Application API (column 7)

This part of the classification describes how developers can alter the appearance or capability of the browser, adding optional functionality or just customizing the appearance with their own branding.

- **Open [key]:** A developer can reuse browser code and APIs to create their own version of the browser and are free to publish the application independently of the platform provider.
- **Restr[icted key]:** A developer can create their own version of the application but license restrictions apply.
- **Comm[ercial key]:** a commercial license or fee is required to develop applications using the framework/API – fee may be waived for educational uses.

- **Custom[ize only]:** The developer cannot add any real functionality to the application but the visual appearance can be changed and optional functionality switched on or off.

Criteria 5: AR content (Column 8)

This part of the classification describes what kind of content can be superimposed on the reality view by the browser. All the browsers we evaluated can display some kind of 2d image or icon in the reality view to represent a Point Of Interest, often representing geographically nearer POIs with larger icon sizes.

- **2d:** POI are represented by 2d image icons, text or bubbles.
- **3d:** a 3d object can be superimposed on the reality (camera) view in 3d space to give the impression that the object is part of the natural environment. The 3d object can be shown from different angle depending on the user's orientation relative the 3d point of origin associated with the model.
- **3d-anim[ated]:** a 3d object is superimposed on the reality (camera) view and parts of the model can be made to move using 3d animation techniques.

Criteria 6: POI actions (Column 9)

This section of the classification looks at the different actions available on an individual Point of Interest. In search mode the user normally sees just an icon, text bubble or a thumbnail. Sometimes a short summary is shown on lower part of the screen for a particular Point of Interest as the icon glides into the central part of display. By pressing either the icon or a link in the summary the user is presented with a list of actions that can be performed on the Point of Interest. The types of action presented will depend on the kind of object the point of interest references.

- **Info:** ability to link to a web page with more information about the object.
- **Audio:** ability to play a sound clip.
- **Video:** ability to play a video clip.
- **Music:** play music track on device music player.
- **Map [Take Me There]:** see POI as pin on map with option to show route from current location to POI location.
- **Search [and shop]:** ability to find search results using search engine or shopping channel.
- **Call:** can click button to make phone call to number in POI response.
- **Email:** can write email message to email address provided in POI response.
- **SMS:** can write SMS text message to mobile number provided in POI response.
- **Social:** various social network actions such as comment, share, profile.
- **Event:** allows user to define their own events when user interacts with POI.

Criteria 7: Offline mode (column 10)

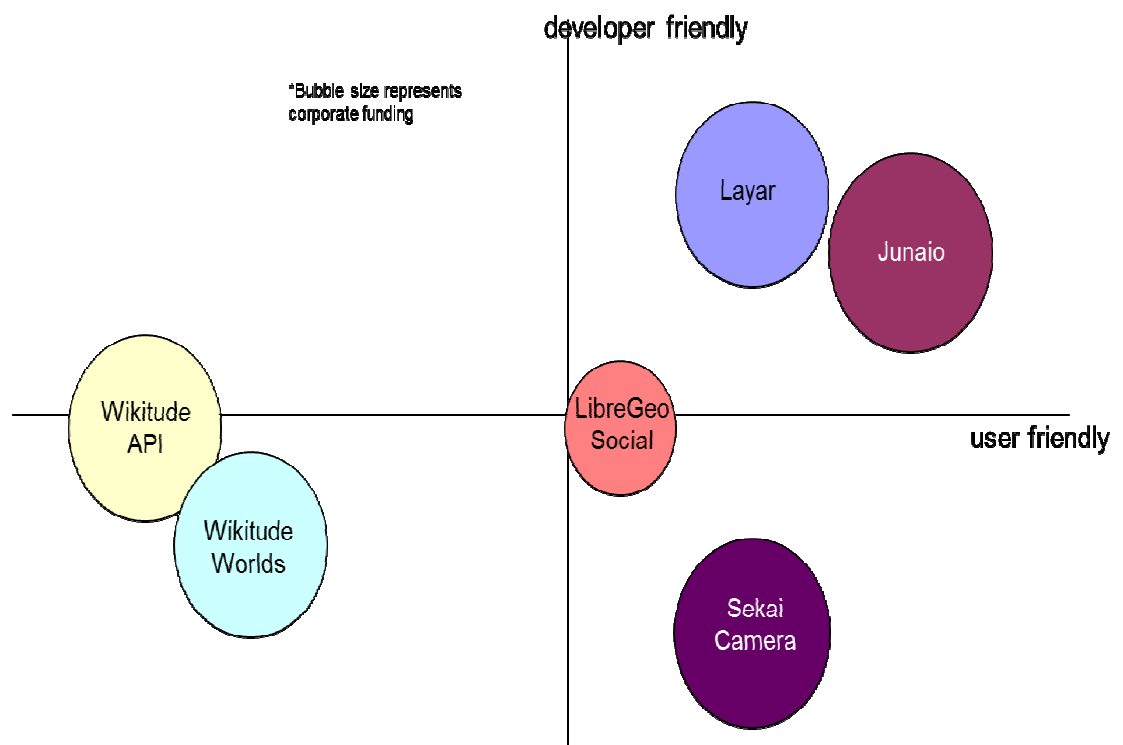
Most of the browsers we evaluated require a constant mobile network connection to operate normally. Some application frameworks allow the user to bundle or cache data into the application so that it can obtain points of interest without a network.

- **Online only:** application requires a network connection at all times to work properly.
- **Offline:** application also works offline – data is updated by obtaining a new version of the application.
- **Cachable [cacheable layer]:** Channels or layers can be cached while online.

User vs. Developer

It is possible to view the criteria in the Comparison Table from the perspective of the user (“I want to do cool stuff”) and from the perspective of the developer (“I want more control of the user experience”). To visualize the browsers were scored against the criteria in the Comparison Table and added an extra “build quality” and “developer tools” criteria to create the bubble chart below. The size of the bubble represents the corporate strength of the organisation behind the browser (measured by number of years in operation, funding profile and number of employees). It goes without saying that charts such as that below need to be taken with a pinch of salt.

User vs. Developer Comparison of AR Browsers



What Was Left Out

Below is a summary of browsers, frameworks and applications left out. Many are standalone applications which are potentially very useful for teaching and learning but do not allow you to publish your own content or change the appearance or behaviour of the user interface. Some do not have the ability to superimpose virtual objects on a camera and therefore are not strictly augmented reality applications, but still provide useful interfaces that could be used in educational contexts. It is recommended you consider these applications and keep up to date with recent browser releases at the Augmented Planet browser section [9].

SREngine

SR-Engine [10] looks like a promising framework for performing visual search but appears to be focused on the Japanese market for the moment. As a result we struggled to get enough English language documentation to fill in our classification matrix and also could not get the app from the UK AppStore.

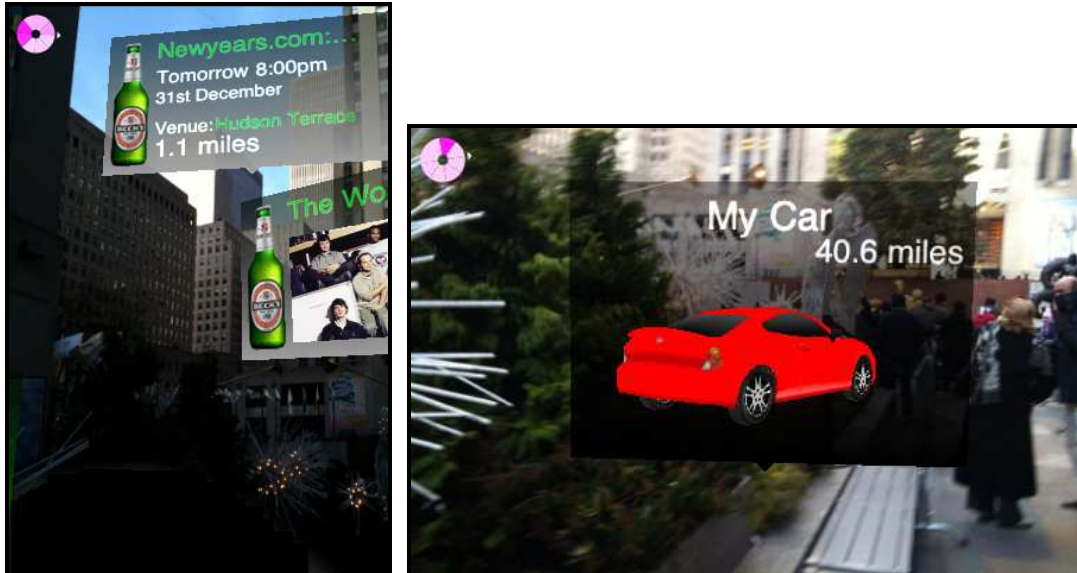
GeoVector World Surfer

World Surfer [11] provides an appealing browser that allows you to point the handset and discover POI. There is a reality view but this only works on a single POI the user has already selected. There does not appear to be any developer access to either publishing or application framework at this point.



AcrossAir

AcrossAir [12] is an AR browser that is sold as a marketing tool to content providers. The vendor controls both publishing and application development so there is not much scope for developers to utilize this platform.



RobotVision

RobotVision [13] one of the most impressive independent AR browsers. But there are no APIs for developers and the project seems to have stalled with no recent updates on the App Store.

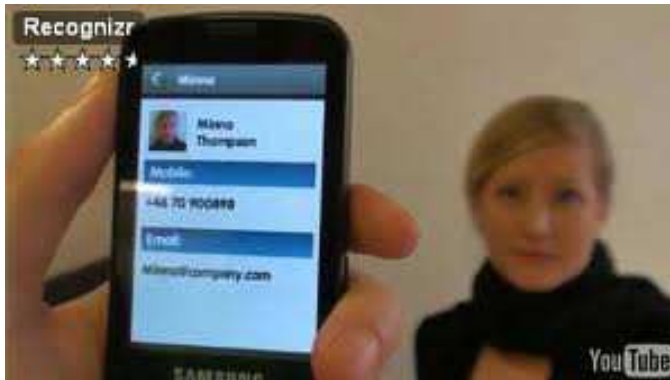
Word Lens

WordLens [14] uses Optical Character Recognition (OCR) technology to translate a sign, menu, book title from one language to another by simply holding up the camera. The translated text is superimposed on top of the reality view. No developer platform but none needed. No doubt there are fantastic learning and teaching opportunities for this app. So far English to Spanish / Spanish to English translation is provided.



Recognizr

The Recognizr [15] face recognition app can display information about a person with links to social network profiles simply by pointing the phone camera at their face. As a standalone app there is not much potential for developers and content publishers.



Kooaba

By strict definition not an AR application, as there is no reality view, Kooaba [16] offers a visual search client for the iPhone that lets the user take pictures of book covers, posters etc. and submit them to a search engine to obtain more information and links to shopping deals. Kooaba does offer a publishing and developer APIs, although some commercial restrictions apply to use.



Google Goggles

Google Goggles [17] is a visual search tool that lets you take a photo of a book cover, landmark or business card and get more information as well as perform actions such as viewing related web page or dialling a phone number. There is no developer access or API yet, but this is not ruled out for future releases.

ImageSpace Browser

ImageSpace [18] is a Nokia (Symbian) based app that displays an AR view of 3d panoramic images stitched together from users photos hosted on Flickr. Appears that Nokia will not develop the application beyond beta research project.



Mixare Browser

A brand new open source framework (released December 2010 and too late for evaluation), Mixare [19] provides a reality view that can display simple Points Of Interest and can dynamically cache the contents of the data providers database on the device with an “App Launcher” feature. The data caching feature makes it innovative and its open license is attractive to developers. Definitely one to watch.



ARToolkit

ARToolkit [20, 21] is a widely used open source AR tracking library that has been used a great deal in educational AR applications since it was first developed by Hirokazu Kato and Mark Billinghurst in 1999 [22]. As well as offering a flexible marker based tracking system, the toolkit enables interaction with virtual objects giving developers the low level tools they require to create rich user experiences. It is maintained as an open source project hosted by SourceForge [23] and has commercial licenses available from ARToolWorks [24]. A port to native iPhone and Android OS are listed at the ARToolWorks site [25] and several other ports (including Symbian) are available elsewhere. The Android library is readily available for download for non-commercial

use while the iPhone library appears to require ordering through a reseller, although it is likely that licenses will be available for non-commercial use. Given ARToolkit's track record in creating hundreds of augmented reality applications, this framework is well worth investigating, particularly for developers already familiar with ARToolkit APIs.

Qualcomm AR SDK

Qualcomm AR (QCAR) platform [27] provides an Augmented Reality SDK that allows developers to create powerful AR applications for a large range of Android devices. The system tracks objects in the real world against reference images using natural feature detection algorithms (markerless tracking). The QCAR developer site offers a user interface so a developer can easily upload and process reference images. The QCAR SDK can even track several images at once depending on performance of the device. Qualcomm offer an extension to the Unity 3D game development tool [28] so that developers can use a familiar game IDE to create QCAR apps. The SDK is now available to developers free of charge. This is definitely a platform you'll want to look at if your application requires markerless tracking - i.e. indoor or near field user experiences.

Resources

- [1] Junaio Home Page, <http://www.junaio.com/>
- [2] Thomas Carpenter, July 2010, "5 Things To Do With Junaio Glue and LLA Markers", Games Alfresco, <http://gamesalfresco.com/2010/07/07/5-things-to-do-with-junaio-glue-and-lla-markers/> (accessed 16/01/ 2011)
- [3] Layar Home Page, <http://www.layar.com/>
- [4] Sekai Camera, <http://sekaicamera.com/>
- [5] Wikitude Home Page, <http://www.wikitude.org/en>
- [6] LibreGeoSocial Home Page, <http://libregeosocial.morfeo-project.org>
- [7] Rose, S. Potter, D. Newcombe, M. November 2011, "A Review of available Augmented Reality packages and evaluation of their potential use in an educational context", University of Exeter. <http://blogs.exeter.ac.uk/augmentedreality/files/2010/11/Augmented-Reality-final.pdf> (accessed 24/02/2011)
- [8] George Papagiannakis, Gurminder Singh, Nadia M. Thalmann, 2008, "A survey of mobile and wireless technologies for augmented reality systems2, in Comput. Animat. Virtual Worlds: <http://www.miralab.unige.ch/repository/papers/486.pdf> , Vol. 19, No. 1, pp. 3-22.
- [9] Augmented Planet Browsers Section <http://www.augmentedplanet.com/category/mobile/ar-browsers/>
- [10] SR-Engine Home Page, <http://www.srengine.com/>
- [11] GeoVector World Surfer, <http://www.geovector.com/applications/world-surfer/>
- [12] AcrossAir Home Page, <http://www.acrossair.com/>
- [13] RobotVision, <http://itunes.apple.com/us/app/robotvision/id329678544?mt=8>

- [14] Wordlens, <http://itunes.apple.com/us/app/word-lens/id383463868?mt=8>
- [15] Recognizr concept video, http://www.youtube.com/watch?v=0QBLKBYrgvk&feature=player_embedded
- [16] Kooaba Home page, <http://www.kooaba.com/>
- [17] Google Goggles Home page, <http://www.google.com/mobile/goggles/#text>
- [18] ImageSpace Browser, <http://betalabs.nokia.com/apps/nokia-image-space>
- [19] Mixare Browser, <http://www.mixare.org/>
- [20] ARToolkit homepage, <http://www.hitl.washington.edu/artoolkit/> (accessed 23/02/2011)
- [21] ARToolkit Wikipedia entry, <http://en.wikipedia.org/wiki/ARToolKit>
(accessed 23/02/2011)
- [22] Kato, H., Billinghurst, M. "Marker tracking and hmd calibration for a video-based augmented reality conferencing system.", In Proceedings of the 2nd IEEE and ACM International Workshop on Augmented Reality (IWAR 99), October 1999.
- [23] ARToolkit SourceForge download site, <http://sourceforge.net/projects/artoolkit/files/>
- [24] ARToolWorks company page, <http://www.artoolworks.com/>
- [25] ARToolworks Mobile products page, <http://www.artoolworks.com/products/mobile/>
- [26] AR Landscape Browsers Page, W3C POI Working Group, 2011, http://www.w3.org/2010/POI/wiki/AR_Landscape/Browsers (accessed 01/03/2011)
- [27] Qualcomm AR, <http://developer.qualcomm.com/ar>
- [28] Unity 3, <http://unity3d.com/unity/>

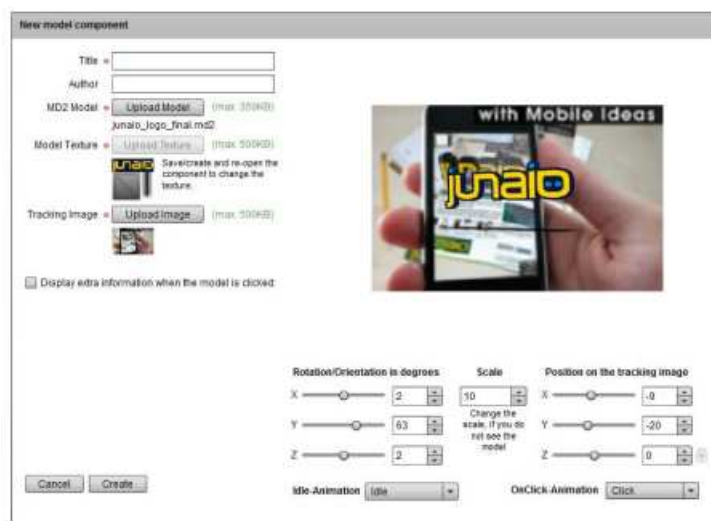
POI Authoring and Publishing Tools

Given the potential complexity of POI data, creating and delivering content to AR browsers can be challenging. Below a list of resources currently available for developers and content publishers to create AR channels more easily are described. Most systems are currently platform centric, hosting and serving POI to just one AR browser, but cross browser Content Management Systems are already emerging, making it easier to share content across AR browsers. As well as CMS platforms, companies such as mCrumbs [19] provide cross browser hosting and publishing solutions within a consultancy model, providing customers with an opportunity to create bespoke applications for popular AR browsers.

Junaio Channel Creator

Junaio's channel creator [1] enables publishers to create their own POI channels without any programming. A point and click interface allows you to upload content such as 3d models and videos, along with tracking images (images used by image recognition system to match against the reality view) and provide information about the content using web forms. All the information is hosted on Junaio's servers, which means the developer does not need to host or maintain their own server.

Adding 3d component in Junio Channel creator [1]



The screenshot shows the 'New model component' form in the Junaio Channel Creator. The form includes fields for Title, Author, MD2 Model (with an 'Upload Model' button and a file name 'junaio_logo_final.ms2'), Model Texture (with an 'Upload Texture' button and a file name 'junaio'), and Tracking Image (with an 'Upload Image' button and a file name 'junaio'). There is a checkbox for 'Display extra information when the model is clicked:'. Below these fields is a preview image of a hand holding a smartphone displaying the Junaio logo. At the bottom, there are sliders for Rotation/Orientation in degrees (X: 2, Y: 63, Z: 2), Scale (X: 10, Y: 10, Z: 10), and Position on the tracking image (X: -8, Y: -20, Z: 0). There are also dropdown menus for 'Idle Animation' (set to 'Idle') and 'OnClick Animation' (set to 'Click'). Buttons for 'Cancel' and 'Create' are at the bottom left.

Junaio Getting Started packages

Junaio offers sample PHP code to help developers get started with developing their own POI provider [2]. Stub code is provided along with examples and instructions on how to install the PHP application to an Apache Web Server. Similar Getting Started package is provided for C# developers with install instructions to .NET environment. In addition, a developer package is provided for more advanced programming libraries supporting large data sets and complex usage scenarios.

Wikitude.me POI publisher

Wikitude offer a web based application called “Wikitude.me” [3] for adding simple POI to the generic Wikitude World browser channel. An online map application allows user to pinpoint a location and then add a text description to the POI.

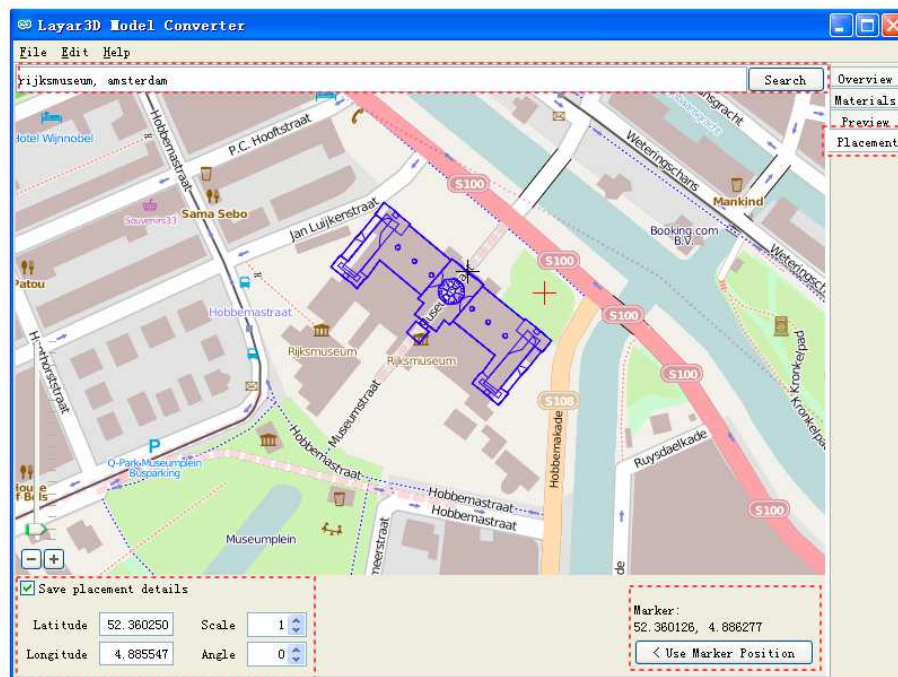
Layar Test Web Page

Layar provides a web page [4] as part of its publishing platform that allows developers to quickly test queries to their POI service. The interface allows the developer to set the location of a user on a map, mimic the user controlled search filters (such as radius of search) and returns the points of interest that would be seen on the Layar client, with locations of POI shown as place marks on the map. The test page shows the raw JSON response that was received so that developer can copy and paste the response text into a validation tool such as JSONLint [5]. While simple this is a very useful tool as it saves the developer from testing on a mobile device, where debugging can be difficult.

Layar 3d model publisher

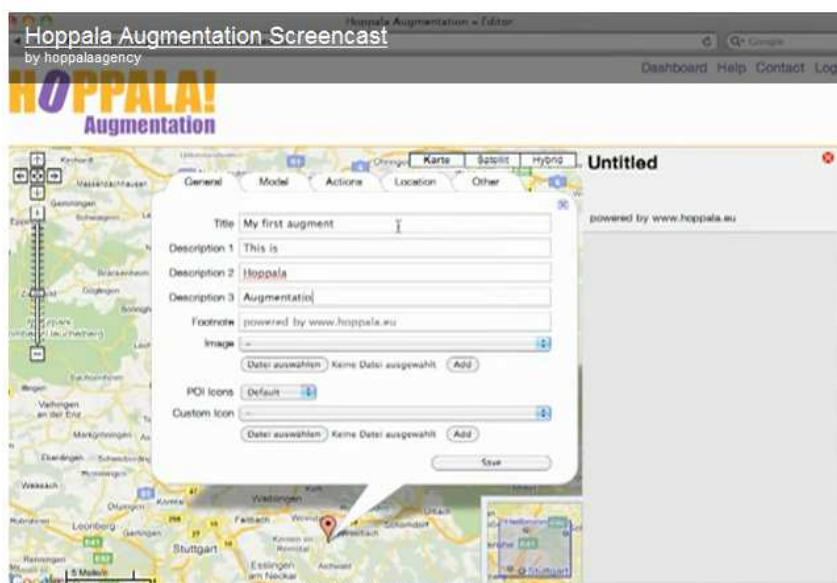
Layar uses its own proprietary 3d object format based on Wavefront .obj files [6]. The 3d model converter [7] allows publishers to upload a standard obj file (created in a 3d modelling tool such as Google Sketch-Up or Blender [8,9]) and converts it to the Layar internal format. The tool adds value to the developer as it gives an indication as to whether an existing 3d model will render properly in Layar or not and there is even a preview tab to help the developer scale and rotate the model as required. Often it is necessary to reduce the complexity of a model (reduce the number of vertices and textures) to meet the restrictions stipulated by the AR browser. Having a tool which effectively validates the model against these requirements is valuable. The latest version of the Layar 3d model converter (version 2.2) also enables the developer to place and scale the 3d object accurately using a map interface.

Placing a model in Layar 3d model converter: 3d model converter [7]



Hoppala Augmentation

Hoppala Augmentation [10] describes itself as a CMS for mobile augmented reality browsers and provides an interface similar to the Junaio Channel Creator that allows non-programmers to create their own channels without any coding. Hoppala provides a web interface and hosting environment. Hoppala started off supporting the Layar browser, uniquely supporting 3d and integrated Layar channel creation [18]. More recently, Hoppala announced additional support for Junaio and Wikitude, making it one of the first to offer cross browser capability. In the absence of agreed standards for publishing Points of Interest, this is a real advantage for publishers who want to reach as many end users as possible.



PorPOISe for Layar

PorPOISe for Layar [11] is an open source Layar backend in PHP. Handles JSON formatting and distance calculations driven from XML or SQL database.

Django-Layar

Django-Layar [12] provides a Python backend implementation for serving Layar POIs

LayarDotNet

LayarDotNet [13] is a Layar POI backend framework is also available for C#/.Net developers

Lightrod

Lightrod [14] Is a further PHP open source Layar backend and also offers hosting services.

Build AR

Build AR [15] is another CMS offering with a map based interface for creating POI and hosting service.

VISAR

VISAR [16] from Muzar.org is another CMS offering POI creation interface and hosting for Layar POI, along with QR code generation.



Resources

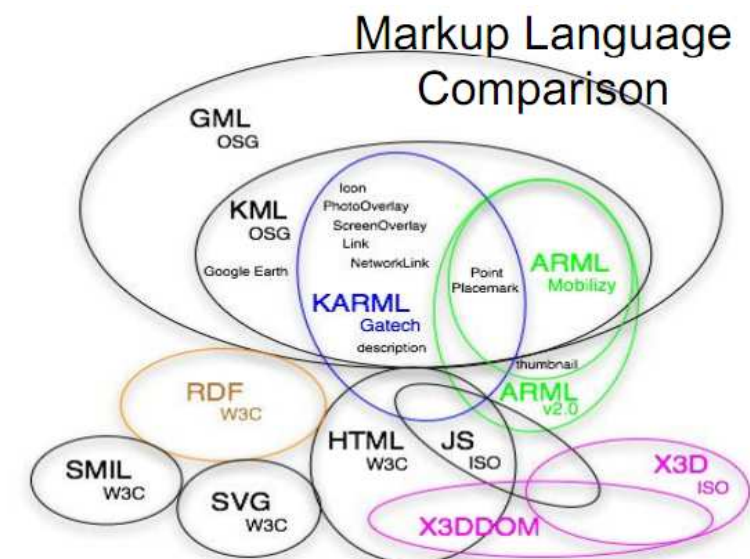
- [1] Junaio Channel Creator, <http://www.junaio.com/create/creator>
- [2] Junaio Getting Started Packages, <http://www.junaio.com/publisher/serversetup>
- [3] Wikitude.me, <http://wikitude.me/map.jsp>
- [4] Layar Test Web Page, <http://layar.pbworks.com/w/page/30677258/Test-a-layer>
- [5] JSONLint validator, <http://www.jsonlint.com/>.
- [6] Wavefront .Obj file format, Wikipedia article,
http://en.wikipedia.org/wiki/Wavefront_.obj_file
- [7] Layar 3d Model Converter, <http://layar.pbworks.com/w/page/32586555/3D-Model-Converter>
- [8] Google Sketch-up, <http://sketchup.google.com/>
- [9] Blender, <http://www.blender.org/>
- [10] Hoopla Augmentation, <http://www.hoppala.eu/>
- [11] PorPOlse for Layar, <http://code.google.com/p/porpoise>
- [12] Django-Layar, <http://pypi.python.org/pypi/django-layar/0.1.0>
- [13] LayarDotNet, <http://layardotnet.codeplex.com/>
- [14] Lightrod, <http://www.lightrod.org/>
- [15] BuildAR <http://buildar.com/index.html>
- [16] VISAR,
http://www.muzar.org/index.php?do=content&id=8&tt=page&parent_id=0&category=mainmenu
- [17] Skaloop, <http://www.skaloop.com/skaloop/index.php>
- [18] Layar Creation Tools Series Wrap Up, December 2010, Layar Blog,
<http://site.layar.com/company/blog/layar-creation-tools-series-wrap-up/>
- [19] mCrumbs homepage, <http://www.mcrumbs.com/>

Standards, Tools and Best Practice Guidelines

Standards

The use of the term “AR browser” to describe applications such as Layar, Junaio etc. suggests these products are comparable to generic web browsers such as Internet Explorer. But while both are technically HTTP user agents and consume content from the web, the comparison ends there. Generic web browsers all adhere more or less strictly to a set of standards for mark-up and MIME types (e.g. XHTML, CSS, jpeg, etc.) and therefore different browsers can consume and render the same web content in a consistent manner. In contrast standards for augmented reality applications are still in their infancy and there is no interoperability between AR “browsers”. This means that content cannot be shared between different browsers and there is no equivalent of Google Search for discovery. Instead a developer publishing some content designed for AR browsers must offer multiple interfaces and formats and upload discovery metadata to each platform they wish to support.

This situation is hardly surprising given the immaturity of both the smartphone and augmented reality technology. With several youthful companies fuelled by venture capital attempting to out-innovate one another, we should not expect a rapid convergence on standards just yet. Eventually AR technology will have to converge on some standard formats and protocols or will otherwise stall as content providers struggle to make their content compatible with multiple platforms. In June 2010, the W3C began the process by holding a workshop “Augmented Reality On The Web” in Barcelona [1], that attracted 40 attendees and 20 papers. There was agreement that a Working Group should be set up to start work in the area of Point of Interest (POI) representation. [2]. A similar workshop on AR standards [3] was held in Seoul in October 2010 and produced several discussion papers and presentations, again many focusing on Points of Interest but also some discussion of related standards such as X3d [4]. The meeting outputs summary presentation includes an interesting comparison of mark-up languages, shown below, which demonstrates the level of divergence in the landscape today.



Source: Jacques Lemordant, International AR Standards Meeting Oct 11-12, 2010 [3]

Another initiative to watch is the AR Consortium [5] which organized the first commercially oriented AR event in June 2010 [6].

Some organisations have attempted to jump start the standards process by proposing Points of Interest mark-up languages based on existing geospatial standards. For example, the ARML specification [7] proposed by Mobilizy builds on Google's KML [8] standard. Similarly the KARML language [9] developed by researchers at the Georgia Institute of Technology, extends KML to allow fine grain control of rendering to support AR interfaces. Both these initiatives have the advantage that the POI data can be consumed by existing (non AR) interfaces such as Google Earth, but so far neither has been taken up by other AR browser providers.

Points of Interest

Despite the lack agreement so far on representations for AR content, it is worth reviewing how different AR platforms (for smartphones) are currently tackling the problem. Perhaps the key consideration is how Points of Interest are represented and delivered to the client application. At first this might seem a simple matter, a mere extension to the "place mark" data type familiar to KML authors. The Wikitude POI object base class illustrates this basic requirement for a POI data type in a simple AR application.

WTPoi-Objects class

```
float latitude (required, the latitude of the POI)
float longitude (required, the longitude of the POI)
float altitude (in meters, the altitude of the POI, defaults to 0)
NSString* name (defaults to "Name unknown")
NSString* shortDescription (defaults to ""; the text which is displayed in the bubble
when the POI is selected)
```

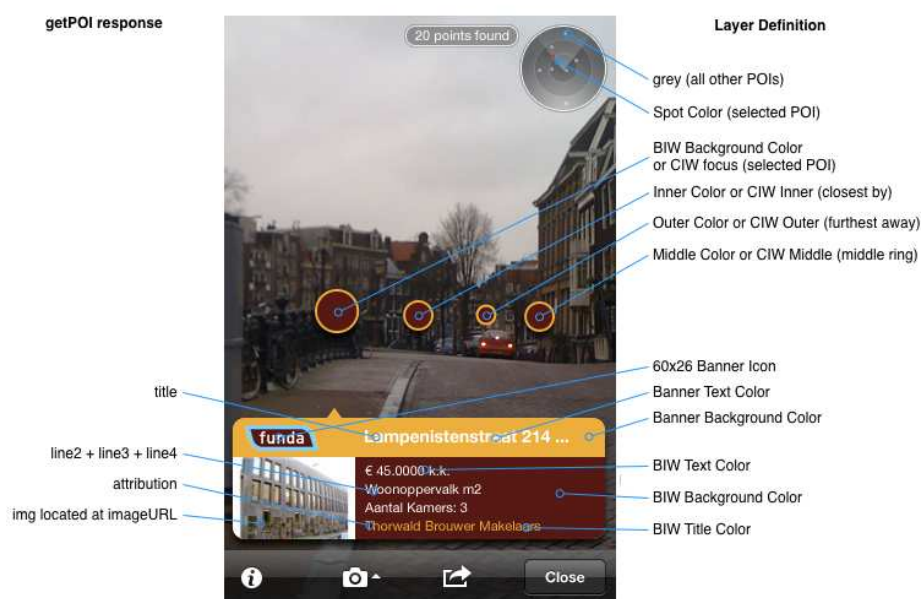

NSString* url (an arbitrary URL called in a WebView when the user clicks on the WWW-button in the bubble of the POI in the AR camera view)

NSString* icon (the URL of the icon representing the POI in the AR view)

NSString* thumbnail (the URL of the thumbnail which should be displayed in the bubble view of a in the AR view)

But this Location Based Service style data type does not suffice for more complicated AR interfaces, as can be seen from the Layar “hotspot” graphic below.

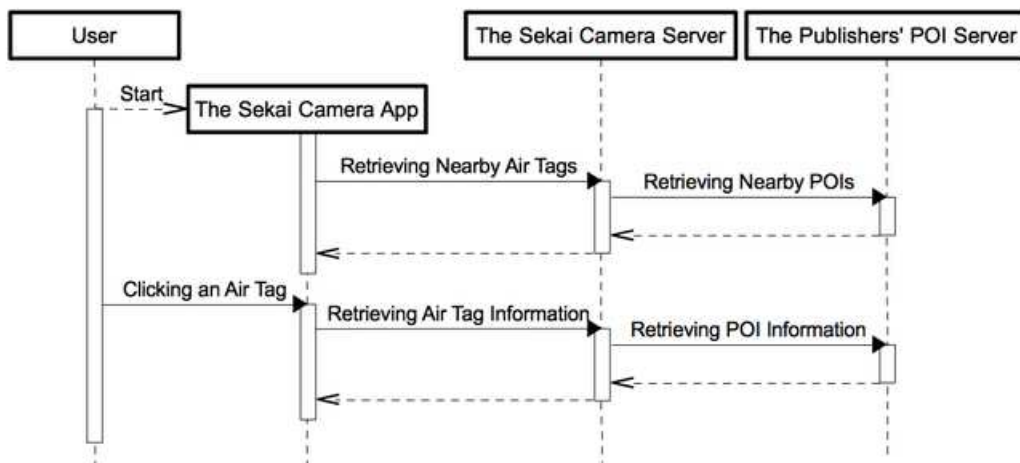
BIW information:



As well as offering more properties for describing buildings and detailed addresses, with affiliated organisations and their logos, the Layar definition offers fine grain control over the colouring of individual icons and text areas. However this is just the start, more complex content such as audio and video and 3d objects need extra attributes. As well as GPS geo-location (longitude, latitude, altitude) other sensor data may be relevant (pitch, roll, bearing). Geospatial entities other than geographic coordinates such as terrains, boundaries and panoramas may also need description in some applications. To create social network applications (e.g. Sekai Camera) where users can create their own content and share it with friends, information on the ownership and access rights to a point of interest is needed. For applications that use image recognition to register digital content (for example superimposing a 3d model of a molecule on a page in chemistry text book) the physical location of the Point of Interest is not important. Instead attributes are needed to describe the reference image used for matching.

Often a distinction is made between a POI data type and POI-Info data type. This relates to the protocol commonly adopted by most AR browsers, where an initial request retrieves all POIs in a specified radius of the user, displaying minimal representation of the content (e.g. just a short description or thumbnail image). The full content (full 2d image or 3d model) is only retrieved

when the user selects a particular Point of Interest from the initial radial search results. This “lazy loading” approach can reduce the application’s use of the mobile network. The Sekai Camera sequence diagram below illustrates this protocol. (POIs are called “Air Tags”).



As can be seen from the examples below the basic request string for the initial radial search is fairly similar across browsers with the longitude, latitude and radius of the search the universal parameters.

Example 1: Layar request

```

http://devAPI.example.com/getPOIs/
?countryCode=IN // language /country
&lon=4.887339 // latitude
&lat=52.377544 //longitude
&timestamp=1249226148713
&userId=ed48067cda // registered user id
&developerId=11233aa6b
&developerHash=1ee6d294a
&radius=6245 // radius of search
&layerName=snowy4 // channel name
&accuracy=100 //minimum GPS accuracy in meters
  
```

Example 2: Junaio Request

```

http://mychannels.exampleurl.com/pois/search/
?uid= ed48067cda // registered user id
&l=37.777933,-122.421455,0 //longitude /latitude and altitude
&p=3000 // radius of search
&m=20 //results per page
(HTTP_ACCEPT_LANGUAGE:en)
  
```

Example 3: Sekai Camera Request

```

http://www.example.com/RetrieveNearbyPoi.json
?key=1264938182ab // developer key
  
```

```
&lat=35.691988 //latitude  
&lon=139.708438 //longitude  
&radius=300 // radius of search  
&limit=100 // max number of results  
&pos=200 //start position in results
```

There are quite significant differences though in the representation of POI-Info objects. This reflects the varied capabilities and approaches of AR browsers in handling content such as 3d models, multimedia and the level of control afforded to developers on the styles, presentation and placement of POI information. Metadata related to image recognition capabilities in the client adds further noise to the general confusion making the task of publishing content to multiple platforms even more daunting. It's pretty clear the standards working groups have a significant challenge ahead of them.

Best practice guidelines

As standards are not yet here to help below is a summary of best practice guidelines that we have collected from various platforms' documentation pages.

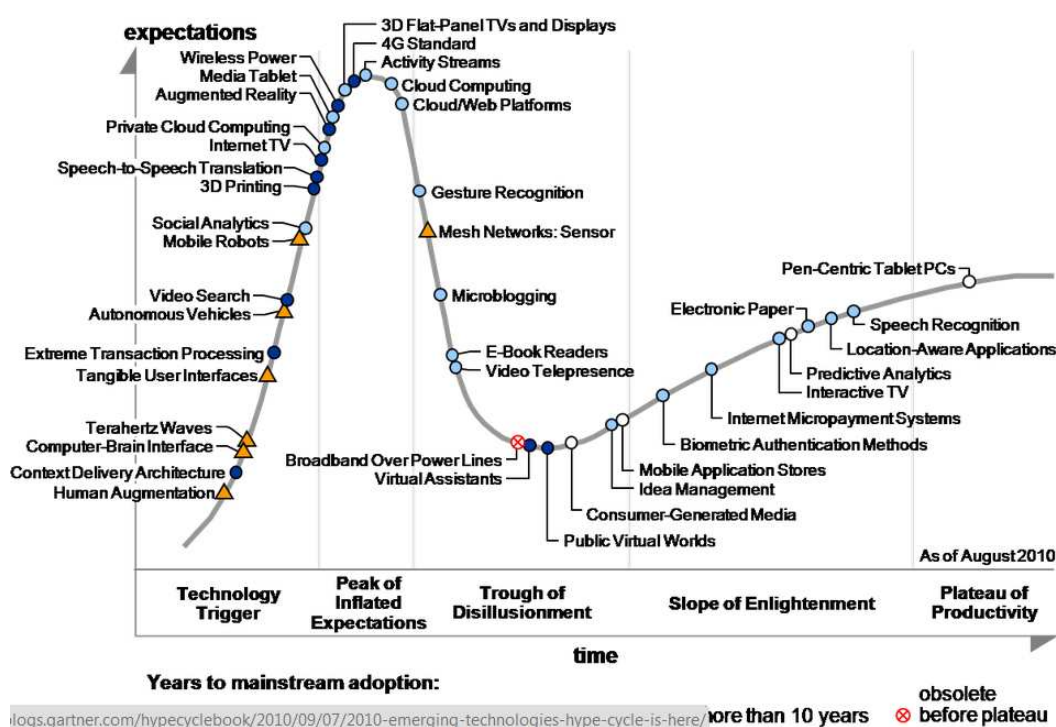
1. Use the radius: In several AR browsers the user is able to specify the radius of a POI search. This reduces the number of POI displayed and minimizes network usage. Therefore the channel should only return POI within the specified radius of the user location.
2. Sending POI in small groups: It can be more efficient to send a list of POIs one by one or in small group rather than as single blob of data. This will allow the client to show some POI as they become available, so that the user sees something is happening even if some POIs are still to be loaded.
3. Use same base colour for different sized POI icons. Some browsers show POIs that are closest as large icons and POI that are further away as middle or small sized icons. Layar recommends that all these icons should use the same base colour, fading to lighter shades as distance increases.
4. Provide reduced models. Some browsers allow the developer to provide alternative content for the POI, depending on the distance and orientation of the user from the POI location. In particular Layar recommends developers provide alternative content for 3d models, that can use a lot of memory to render on the device and therefore should only be loaded when the user is at the correct location or orientation to view it properly. A 2d image or thumbnail can be used to render the object from further distances.
5. Use paging. Because users receive POI over-the-air paging is recommended for results of 15 POI or more (Layar).
6. Keep result set small. Do not return more than 50 POI. If a search produces more than 50 POI in the radius of the user return the 50 closest or most relevant only (Layar)

Resources

- [1] Augmented Reality On The Web workshop, Barcelona 2010,
<http://www.w3.org/2010/06/w3car/report.html> (accessed 28/01/2011)
- [2] WC3 Point Of interest Working Group (POI WG), 2010, Barcelona,
<http://www.w3.org/2010/POI/> (accessed 28/01/2011)
- [3] International AR Standards Meeting, 2010, Souel,
<http://www.perrey.com/ARStandardsMeetingOutputs.html> (accessed 28/01/2011)
- [4] X3d Draft Specification, Web 3d Consortium,
<http://www.web3d.org/x3d/specifications/x3d/> (accessed 28/01/2011)
- [5] The AR Consortium, <http://www.arconsortium.org/> (accessed 28/01/2011)
- [6] The Augmented Reality Event, 2010, Santa Clara,
http://augmentedrealityevent.com/category/augmented_reality_event_2010/ (accessed 28/01/2011)
- [7] ARML Specification For Wikitude 4, Mobilzy, <http://www.openarml.org/wikitude4.html> (accessed 28/01/2011)
- [8] KML Reference, Google Inc.,
<http://code.google.com/apis/kml/documentation/kmlreference.html> (accessed 28/01/2011)
- [9] KARML Reference, Georgia Institute of Technology School of Interactive Computing,
<https://research.cc.gatech.edu/polaris/content/karml-reference> (accessed 28/01/2011)
- [10] Petri Selonen, Petros Belimpasakis, and Yu You. 2010. Developing a ReSTful mixed reality web service platform. In Proceedings of the First International Workshop on RESTful Design (WS-REST '10), Cesare Pautasso, Erik Wilde, and Alexandros Marinos (Eds.). ACM, New York, NY, USA, 54-61. DOI=10.1145/1798354.1798387
<http://doi.acm.org/10.1145/1798354.1798387>

User Experience Design and Anti-Patterns

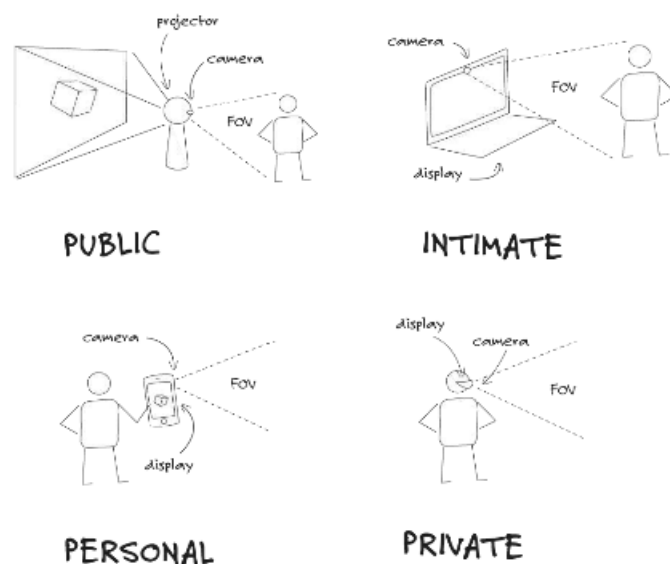
Now that AR has moved on from the lab and started to emerge into real world environments, particularly in the form of smartphone apps, people are beginning to examine the issues around user experience and the dynamics of social interactions that AR technology can raise. Research in this area is sparse, but some consensus is already emerging that user experience (UX) issues could be a major barrier to widespread adoption of AR. It is important for anyone developing an AR application to be aware of the implications that AR technology has on normal modes of social interaction. While the Gartner 2010 Emerging Technologies Hype Cycle report [1] places AR near the "peak of inflated expectations" some commentators have already arrived at the "Trough of Disillusionment", with Illya Vedrashko's review of AR microsites [2] concluding that the "wow" quickly depreciates to "meh" and David Klein picking up on the social awkwardness of holding up a phone in front of your face for several minutes in his blog post "You Look Ridiculous: The Other Augmented Reality Issue" [3].



Source: Gartner 2010 Emerging Technologies Hype Cycle [1]

To get a better understanding of challenges to creating effective user experiences we look below at two attempts to describe the types of user experience that have emerged from recent development in AR technology.

Alex Young from MOB Labs [4] categorizes AR user experience in terms of the level of privacy, field of vision constraints and ability to distribute the experience [5], as seen in the diagram below.



To summarise Young's talk, the "Public" AR user experience typically involves several spectators with the display projected onto a public viewable surface, one camera tracking a marker or natural feature and a separate camera providing the "reality view" feed. As the experience requires a projection, distribution is limited because the set up cannot be moved easily from one place to another. This "public" user experience is not possible with existing smartphone based AR offerings although a future generation of smartphones with built in or accessorized pico projectors may open up possibilities for more participants.

The "intimate" user experience typically involves a desktop PC or laptop equipped with a web cam. The user can print off a marker and hold this up to the web cam which provides the "reality view" (typically upper torso) feed that is augmented with virtual objects. The computer display allows more than one viewer but the number of spectators is limited to the monitor's angular display qualities. For most smartphone devices this user experience is difficult as the user has to line up the printed marker and the camera while at the same time positioning the smartphone display into their field of vision. More recent smartphone models with both front and back facing cameras should make this kind of user experience easier, although interactions involving more than one spectator will remain problematic.

The "personal" user experience involves the user holding a small mobile device with built-in camera and display. This is the dominant user experience offered by smartphone devices. While the system can work almost anywhere (wide distribution) the experience is typically limited to 1 to 2 people.

The "private" user experience involves just one participant using a wearable camera and display. Potentially distribution is wide but very few systems are available currently.

Young's analysis highlights both the level of privacy and the number of participants involved in the user experience as important, hinting at the implications on social interaction engendered by

the different user experiences. The social consequences of AR technology is the central theme of Joe Lamantia's description of AR user experience patterns [6], outlined below.

Tricorder Pattern

The user holds up a device, similar to the Star Trek "tri-corder" device that analyses the environment surrounding the user and displays digital information through a handheld display.



“Heads-up display” (HUD)

Augmented content is projected onto a surface in the real world environment so that augmented information is displayed without the viewer having to look away from their usual view point.



Holochess pattern

A 3d model, animation or graphic is anchored to a pattern or marker in the real world.



X-Ray vision

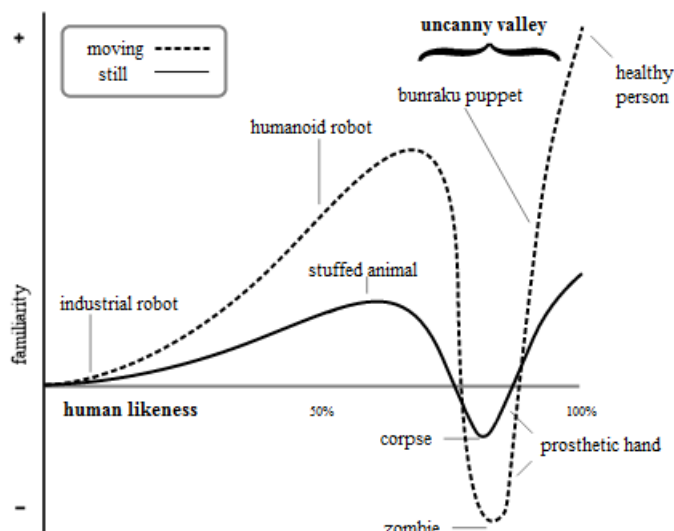
The user can “see through” opaque objects in the real world to reveal internal details represented as graphics or 3d models superimposed on the real world object.



Image from Metaverse One on TweetPhoto [7].

Lamantia considers these four patterns a fairly limited palette for creating rich user experiences. Smartphones in particular are restricted in the types of user experience they can offer. Apps with image or pattern recognition such as Junaio are capable of creating “HoloChess” experiences and in some circumstance “X-Ray” vision may also be possible using both image recognition and location based registration techniques. But currently the “Tricorder” pattern dominates smartphone based AR. If deployed carelessly the Tricorder pattern can create what Lamantia calls “anti-social” experiences comparable to voyeurism or police “stop and search” practices. Lamantia also highlights the “Uncanny Valley” phenomenon, originally developed by roboticist Masahiro Mori, where almost - but not quite - human likeness and behaviour creates a strong negative reaction [8].

The “Uncanny Valley” (Masahiro Mori): source Wikipedia [9]



The personal nature of many AR user experiences (highlighted by Alex Young) means it is particularly important to indicate presence and status of AR components to all participants (“ON AIR” indicator) to avoid socially damaging power asymmetry. Lamantia urges us to design experiences that echo human behaviour and expectations and given the immature state of AR technology to stay off the critical path ensuring that augmentation is optional.

In terms of UI design itself, the AR developer might be limited by the constraints imposed by the browser on how POI’s are displayed in the client. If these restrictions result in an awkward or anti-social user experience, an open source framework such as GeoSocialLibre or Wikitude API might be a better option, even if it requires more effort to produce.

The social awkwardness issue might turn out to be less of a barrier in teaching and learning. Applications supporting self-study are well suited to the “personal” user experience that Alex Young highlighted as typical of handheld AR. Where groups of students are participating interactively in learning activity, normal social constraints are often relaxed. Talking loudly about a painting in an art gallery might flout expectation of quiet contemplation, but in a teaching and learning context disruption to other visitors is accepted. Nevertheless, developers need to consider how students will feel holding up a smartphone in front of their face for several minutes when designing a learning experience.

Focussing on the design of mediascape [10] user experiences, Reid et al. [11] highlight the need to “design for coincidence”. Their studies into how users are able to immerse themselves in a virtual world suggest that “unexpected connections between the physical and virtual worlds” helps the user to see past the technology and engage with the experience. Examples of these connections are hearing a description of lovers on a bench and then noticing some in front of you, or hearing a seagull cry in the headphones and then seeing one fly past.

It is easy to become overly sceptical about the “gimmick” factor any new technology brings. A balancing observation comes from the artist Helen Papagiannis [12], who reminds us that our natural “wonderment” of technology can be as entrancing as the content [13]. Comparing augmented reality to early experiments in film, Papagiannis argues this magical quality and novelty of augmented reality is not something we should discard too readily. The human instinct to understand the “trickery” behind a new perspective on reality is “immersive” in its own way and

can be harnessed to engage users with both the content and technology at the same time. Therefore, while some caution is needed in applying AR to educational contexts, developers and publishers should not be too discouraged by the “social immaturity” surrounding this novel technology.

Resources

- [1] Gartner 2010 Emerging Technologies Hype Cycle, September 2010, <http://blogs.gartner.com/hypecyclebook/2010/09/07/2010-emerging-technologies-hype-cycle-is-here/>
- [2] Ilyia Vedrashko, May 2009, “Augmented Reality Microsites: First Impressions”, <http://adverlab.blogspot.com/2009/05/augmented-reality-microsites-first.html> (accessed 28/01/2010)
- [3] David Klein, March 2010, “You Look Ridiculous: The Other Augmented Reality Issue”, <http://gigaom.com/apple/you-look-ridiculous-the-other-augmented-reality-issue/> (accessed 28/01/2010)
- [4] MOB (Mobile Online Business) Labs, <http://mob-labs.com/index.html>
- [5] Alex Young, 2010, “AR UX: The Generation of the Pervasive User Experience”, UX Australia, <http://www.uxaustralia.com.au/conference-2010/ar-ux-the-generation-of-the-pervasive-user-experience>, accessed 28/01/2010
- [6] Joe Lamantia, 2010, “Social Interaction Design For Augmented Reality: Patterns and Principles for Playing Well With Others2, The Web And Beyond 2010 (TWAB2010) slideshare http://www.slideshare.net/moJoe/social-interaction-design-for-augmented-reality-patterns-and-principles-for-playing-well-with-others?from=ss_embed (accessed 28/01/2010) video, <http://www.joelamantia.com/user-experience-ux/video-of-social-interaction-design-for-augmented-reality-from-twab-2010> (accessed 28/01/2010)
- [7] Damon Hernandez, “Metaverse One” blog, <http://damonhernandez.blogspot.com/> Image bookmark, <http://plixi.com/p/8184908> (accessed 26/01/2011)
- [8] Mori, Masahiro (1970). Bukimi no tani The uncanny valley (K. F. MacDorman & T. Minato, Trans.). Energy, 7(4), 33–35. (Originally in Japanese)
- [9] Uncanny Valley, article Wikipedia, http://en.wikipedia.org/wiki/Uncanny_valley (accessed 28/01/2011)
- [10] HP Mscape, HP Labs, <http://www.hpl.hp.com/mediascapes/> (accessed 16/02/2011)
- [11] J. Reid, R. Hull, K. Cater and C. Fleuriot, **Magic Moments in Situated Mediascapes**. In: ACM SIGCHI International Conference on Advances in Computer Entertainment Technology ACE 2005, ACM June 2005.
- [12] Helen Papagiannis, 2010, “Augmented Stories” blog,

<http://augmentedstories.wordpress.com> (accessed 16/02/ 2011)

[13] Helen Papagiannis, 2010, "How Does Wonderment Guide the Creative Process", TEDxYorkU, YouTube, <http://www.youtube.com/watch?v=ScLgtkVTHDc> (accessed 16/02/ 2011)

[14] The Case Against Augmented Reality, January 2010, Augmented Planet, <http://www.augmentedplanet.com/2010/01/the-case-against-augmented-reality/> (accessed 26/01/2011)

Augmented Reality in Education

Uptake of smartphone based AR in education has been very modest so far. We have not found any examples of channels being created in existing AR browsers such as Layar and Junaio that are specifically geared towards learning and teaching. Most likely, this is due to the immaturity of both the AR browsers and tools for publishing content rather than aversion to the idea of augmented reality itself [1]. In fact quite a large body of work using the previous generation of AR tools (such as ARToolkit [2]) demonstrates enthusiasm among educators for using augmented reality in schools and colleges. Karen Hamilton [3] provides an excellent review of existing work on AR in Education highlighting the five distinct categories of educational experience:

1. Training
2. Discovery Based Learning
3. Educational Games
4. Creating 3d models
5. Augmented Books

Training

AR training applications provide step by step instructions to guide user through completing a complex task with virtual information helping them to identify targets and improve decision making. Most systems employ a head mounted display so that the users' hands are free to perform tasks such as the BMW workshop application [4] below.



BMW video showing use of AR to assist car maintenance [4].

As handheld smartphone browsers do not support this kind of “heads-up” user experience, there are few if any training applications suited to smartphone AR browsers.

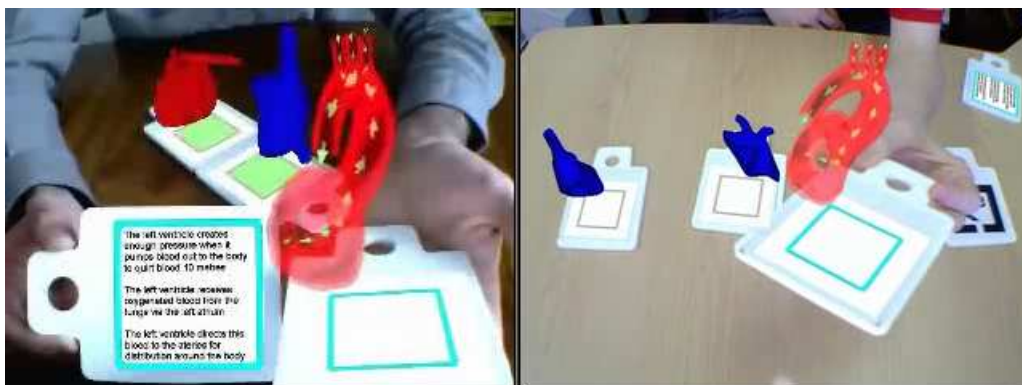
Discovery Based Learning

In Discovery Based Learning users are able to find their own route to achieving learning goals and augment the learning experience by accessing virtual information at their own initiative. This category often involves handheld devices, for example, the Google Sky Map [5] application for Android (not strictly AR as there is no reality view) helps users to explore the night sky and learn for themselves how to recognize constellations and locate planets. Most examples of smartphone AR in education all fall into this category.



Google Sky Map application [5]

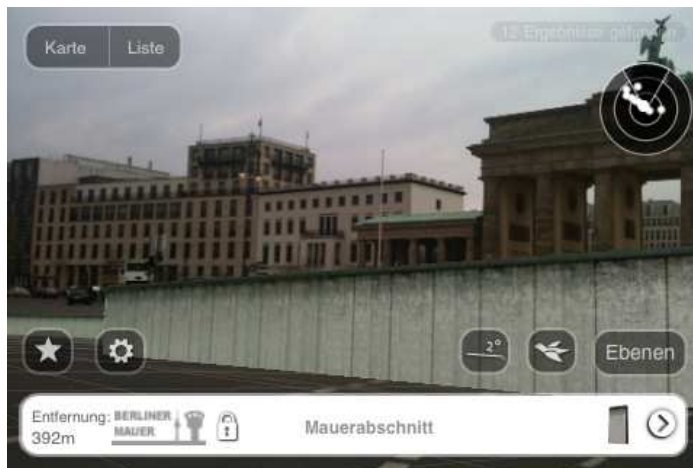
Much previous work on Discovery Based Learning using AR focused on web cam systems, such as the suite of learning experiences offered by Imaginality [6], including the “Building The Human Heart” [7] application shown below.



Imaginality “Building The Human Heart” demonstration [7]

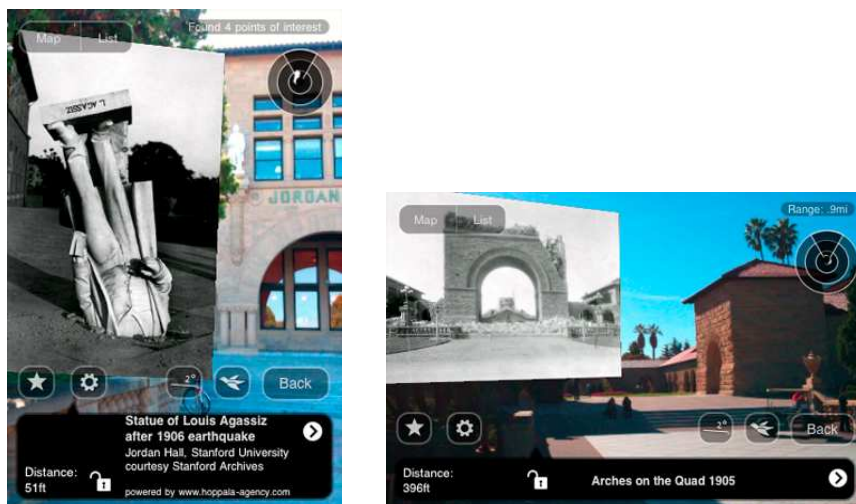
It's not clear if these web cam based exercises will migrate easily to smartphone systems. The distinction Alex Young [8] makes between "intimate" (web cam) experiences and "personal" (handheld devices) suggests that the crossover could be problematic until new affordances such as Near Field Communication (RFID) and built-in pico projectors become available in smartphones.

The few educational augmented reality experiences that have already surfaced on smartphones have been "windows to the past", offering users an opportunity to discover the hidden history of the landscape, buildings and environment during field trips. One example is the Berlin Wall application featured on Layar web site [9] offering an opportunity to see how the city was divided during the Cold War.



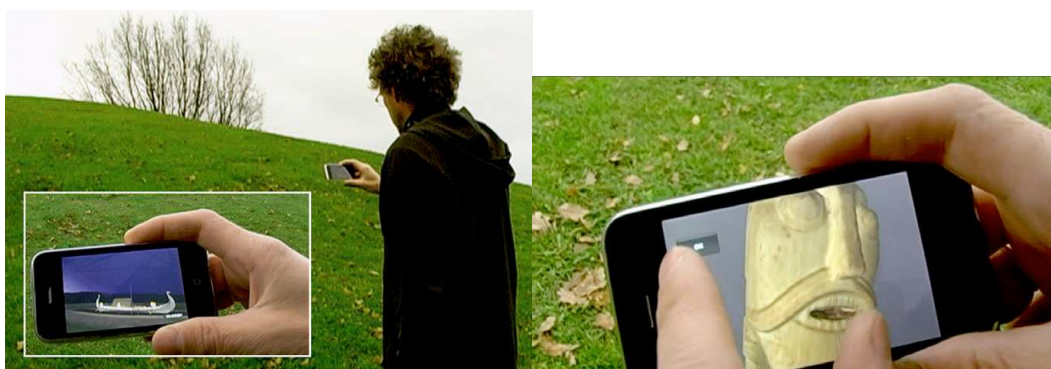
Layar channel that shows how Berlin Wall divided city before it was torn down [9]

An experiment undertaken by Lightning Laboratories [10], tells the story of the 1906 earthquake in San Francisco by placing historical photographs onto the contemporary view. The authors describe a rapid prototyping exercise using Layar and Hoopala, showing what can be achieved in a short time with existing tools. The prototype includes a famous archive picture of a statue that fell headfirst into the ground shown at its present day location, creating what the authors refer to as "magic moment" (citing Reid et al. [11]) of connection between the virtual and the real worlds.



Story of 1906 San Francisco earthquake in Layar with archive picture showing a statue that fell into ground placed against its current location and the site of an arch that was destroyed [10]

The most in depth research into the pedagogical potential of AR in smartphones comes from Gunnar Liestol's team at the University Oslo and their work on "situated simulations" [12, 13]. While not technically AR, the situated simulations software Liestol's team have developed has a similar user experience, with a "clean screen" 3d model of the landscape replacing the reality view. An example application, tested on a field trip with high school students, is the reconstruction of the Oseberg Viking Ship [14]. As well as showing a model of the ship in its landscape, the user can drill down and inspect detailed parts and artworks discovered on the site, allowing students to discover their own connections with the site and its archaeological artefacts. Papers on the pedagogical impact of the study highlight the technical issues with sunlight and students sharing a device, but on the whole the feedback was positive about the learning potential of the technology [14, 15].



reconstruction of the Oseberg Viking Ship showing 3d model of ship and burial mound and ability to drilldown to detailed parts of the model [14]

While few smartphone based discovery based learning applications are available at the moment, some projects are in the pipeline such as the “Unlocking the Hidden Curriculum” project at the University of Exeter [16]. This project aims to create a campus-based Augmented Reality environment in which smartphone users will be able to access scientific data collected about flora and fauna. The application will deliver (2d) graphical and multimedia AR content through AR browsers and the project blog reports on a pilot application based on the Layar platform [17].

Educational Games

Augmented reality games involve role play, team work and a sense of excitement to engage students in learning experiences. A key distinction from Discovery Based Learning is the social interaction and role playing involved in these games. The Click!Online AR game [18] from the Girls, Math & Science Partnership is a good example, where students play the role of “agents” solving biological and environmental mysteries in fictional spy school. The game attempts to create an online community with a Facebook page and real time geo-location tracking of participants. A similar “environment detective” game is described by the MIT Teacher Education Program [19]. Naturally, this style of learning tends to focus on primary and secondary education rather than higher education, although role playing games have been employed in college environments too, for example simulating work experience placements [20]. We are not aware of education games emerging yet for smartphone AR browsers such as Layar, although games are a key market for these platforms.



Screen captures from Click!Online video highlighting role playing and social network features of educational games [18].

Creating 3d models

AR has also been used in education as a visualization tool helping students bring 3d models to life. This is particularly prevalent in architecture and urban landscape subjects for example the AR-Media plugin [21, 22] for Google SketchUp. Researchers from Visual Media Lab at Ben Gurion University went one step further, demonstrating a system that looks at a 2D sketch drawn on paper and renders the image in 3D on the webcam video stream. The 3D rendering is subjected to a physics simulation of one object sliding down the slope of another.

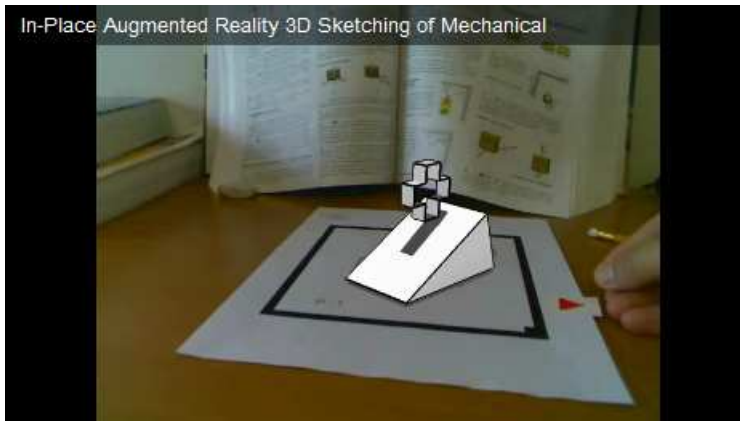
So far the marker/web cam based solutions have not migrated to smartphone browsers and platforms. The limited image processing functions supported by the current crop of AR browser applications may well act as a barrier to replicating these 3d visualization experiences.



AR-Media Plugin (Inglobe technologies) [21, 22]



"In-Place" 3d sketching video: draw model with pencil on paper surface [23, 24]



“In-Place” 3d sketching video: drawing is rendered as 3d object and subject to mechanical simulation (sliding down slope of second 3d object) [23, 24]

Augmented books

A very promising application of AR to education is augmenting existing text books with 3d models, animations and other multimedia to deepen the information provided by text, images and diagrams. This provides students with supplementary material that they may need to properly understand the body of text in the curriculum. Thailand's Institute for the Promotion of Teaching Science and Technology (IPST) demonstration of a marker based textbook for teaching geology to high school students [25] is a good indication of the state of the art.



IPST Augmented Reality Books: student directs webcam at markers in book [25]



IPST Augmented Reality Books: 3d globe model is tracked on marker. Student can perform actions on model by bring action markers into view [25].

Again there is a history of adoption and experimentation using the pre-smartphone generation of AR toolkits, but so far few have transferred to the smartphone applications. This is most likely because early AR browsers did not support image recognition tracking. We expect that with browsers such as Junaio offering marker and markerless feature tracking, applications augmenting books on smartphones will emerge over the next couple of years [1].

Resources

[1] Johnson, L., Smith, R., Willis, H., Levine, A., and Haywood, K. (2011). "The 2011 Horizon Report". Austin, Texas: The New Media Consortium.

[2] ARToolKit home page, <http://www.hitl.washington.edu/artoolkit/> (accessed 16/02/2011)

[3] Karen E. Hamilton, 2011, WikEd, CTER, Department of Educational Psychology, College of Education, University of Illinois at Urbana-Champaign,
http://wik.ed.uiuc.edu/index.php/Augmented_Reality_in_Education (accessed 09/02/2011)

[4] BMW Augmented Reality Workshop, BMW Research,
http://www.bmw.com/com/en/owners/service/augmented_reality_workshop_1.html
(accessed 16 February 2011)

[5] Google Sky Map home page, <http://www.google.com/mobile/skymap/> (accessed 16/02/2011)

[6] Imaginality Markerbased Education Software. Mindspace Solutions,
<http://www.mindspacesolutions.com/imaginality/iuhome.html> (accessed 16/02/2011)

[7] Imaginality "Building The Human Heart" demonstration,
http://www.mindspacesolutions.com/imaginality/html/build_the_heart.html (accessed 16/02/2011)

- [8] Alex Young, 2010, "AR UX: The Generation of the Pervasive User Experience", UX Australia 2010,
<http://www.uxaustralia.com.au/conference-2010/ar-ux-the-generation-of-the-pervasive-user-experience> (accessed 28/01/2010)
- [9] maurice, April 2010, "The Berlin Wall Is Back", Layar blog, <http://site.layar.com/company/blog/the-berlin-wall-is-back> (accessed 16/02/2011)
- [10] Gene Becker, November 2010, "Experiments in Historical Augmented Reality",
<http://www.lightninglaboratories.com/tcw/2010/11/experiments-in-historical-augmented-reality/> (accessed 16/02/2011)
- [11] J. Reid, R. Hull, K. Cater and C. Fleuriot, **Magic Moments in Situated Mediascapes**. In: ACM SIGCHI International Conference on Advances in Computer Entertainment Technology ACE 2005, ACM June 2005
- [12] Liestøl, G. **Situated Simulations: Designing a Mobile Augmented Reality Genre**
INVENTIO-project, Dept. of Media & Communication, University of Oslo
<http://inventioproject.no/sitsim/> (accessed 22 February 2011)
- [13] Liestøl, G. **'Learning through Situated Simulations: Exploring Mobile Augmented Reality.'** (Research Bulletin 1, 2011). Boulder, CO: EDUCAUSE Center for Applied Research, 2011 (open access, registration required)
- [14] Liestøl, G and Rasmussen, T. **'In the Presence of the Past. A field trial evaluation of a situated simulation design reconstructing a viking burial scene'** in Szűcs, A. and Tait A. W. (Eds.) Media Inspirations for Learning. Proceedings of EDEN 2010. Budapest: EDEN Secretariat, Budapest University of Technology and Economics 2010.
<http://inventioproject.no/sitsim/Liestol&Rasmussen%E2%80%93EDEN2010.pdf> (accessed 22nd February 2011)
- [15] Fleischer Orkelbog, V. **'Situated Simulation as a Learning Tool – Experiencing Forum Iulium with the iPhone'** in Kinshuk et. al. (Eds.) Proceedings of Cognition and Exploratory Learning in the Digital Age (CELDA 2010), IADIS Press.
http://inventioproject.no/sitsim/Pages_from_CELDA2010.pdf
- [16] Duune, E. Newcombe, M. Rose, S. Potter, D. "Unlocking The Hidden Curriculum" Project, University of Exeter, <http://blogs.exeter.ac.uk/augmentedreality/about/> (accessed 22nd February 2011)
- [17] Duune, E. Newcombe, M. Rose, S. Potter, D. "Pilot AR System in Testing", University of Exeter, <http://blogs.exeter.ac.uk/augmentedreality/blog/2011/01/27/pilot-ar-system-in-testing/> (accessed 22nd February 2011)
- [18] "Click!Online" YouTube promotional video, Girls, Math & Science Partnership (GMSP) at Carnegie Science Center, Pittsburgh, <http://www.youtube.com/watch?v=wftv4OGyZuE> (accessed 22nd February 2011)
- [19] "MITAR Games", MIT Teacher Education Program, (with EducationArcade
<http://education.mit.edu/projects/mitar-games> (accessed 22/02/2011)

- [20] Cornelius, S., Medyckyj-Scott, D., Forrest, D., Williams, A. and Mackaness, W. (2008) The virtual placement: an alternative to the traditional work placement in the geographical sciences? *Journal of Geography in Higher Education*, 32 (2). pp. 287-302. ISSN 0309-8265
- [21] AR-Media Plugin for Google Sketch-Up, Inglobe Technologies,
http://www.inglobetechnologies.com/en/new_products/arplugin_su/info.php (accessed 22/02/2011)
- [22] AR-Media plugin video featured on Digital Urban blog,
<http://www.digitalurban.org/search/label/Augmented%20Reality> (accessed 22nd February 2011)
- [23] Oriel Bergig, Nate Hagbi, Jihad El-Sana, and Mark Billinghurst. 2009. In-place 3D sketching for authoring and augmenting mechanical systems. In *Proceedings of the 2009 8th IEEE International Symposium on Mixed and Augmented Reality (ISMAR '09)*. IEEE Computer Society, Washington, DC, USA, 87-94. DOI=10.1109/ISMAR.2009.5336490
<http://dx.doi.org/10.1109/ISMAR.2009.5336490>
- [24] Oriel Bergig, Nate Hagbi, Jihad El-Sana, and Mark Billinghurst "In-Place "Augmented Reality 3D Sketching of Mechanical Systems" Video, YouTube,
http://www.youtube.com/watch?v=M4qZ0GLO5_A (accessed 22/02/2011)
- [25] Cameron, C. July 2010, AR Textbooks, "Virtual Chemistry Sets & the Future of Learning" ReadWriteWeb,
http://www.readriteweb.com/archives/ar_textbooks_virtual_chemistry_sets_the_future_of_learning.php (accessed 22/02/2011)

Concluding Remarks

Thanks to advances in smartphone technology augmented reality is accessible to a wide audience for the first time. A new class of AR “browser” and tools for authoring and hosting content makes it possible for almost anyone to create augmented reality learning experiences. As an emerging technology, the industry lacks standards and consistency which means it can be difficult to create applications that work across several browsers. Educators should understand the limitations and potential pitfalls associated with this nascent medium. Both technical and social issues with current smartphone AR offerings could lead to disillusionment once the initial “wow” factor fades. As long as content creators work within these limitations there is huge potential for teaching and learning and it will get easier to participate as tools and frameworks mature. With several energetic young companies, fuelled by venture capital, vying to out-innovate one another, the prospect for more powerful browsers and even better authoring and publishing tools looks bright.

As new hardware capabilities such as faster processors, 3d graphic accelerators, Near Field Communication and projectors develop in future smartphone devices even more exciting possibilities for educators will emerge. In this projection, 2011-12 will be a good time to experiment with augmented reality technology for the first time. While the novelty factor will depreciate quickly, the technology itself will stick and evolve along with mobile and ubiquitous computing. So as long as you are expecting things to change rapidly you will be riding a wave of change in publishing and educational content provision that is likely to shape the next decade of advances in education.

General Resources

The following sites have been an invaluable source of information about augmented reality.

- Augmented Planet: <http://www.augmentedplanet.com/>
- Games Alfresco: <http://gamesalfresco.com/>
- Augmented blog <http://augmentedblog.wordpress.com/page/6/>
- Damon Hernandez, "Metaverse One" blog, <http://damonhernandez.blogspot.com/>
- Not Just Reality, Trevor Mendham <http://www.notjustreality.com/lead-story/135-android-augmented-reality-from-gamaray/>
- Augmented Reality Games blog: <http://augmented-reality-games.co.uk/>